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STUDY PAPER
FOR THE SPECIAL ADVISOR TO THE CHIEF OF DEFENCE STAFF ON OFFICER PROFESSIONAL DEVELOPMENT

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ABSTRACT

This DREV document is the answer to a request from the Special Advisor to the Chief of the Defence Staff to assess the state of Information Technology in year 2020. The result of this work will support an analysis of the formation requirements of Canadian Military Officers to meet the challenges and demands imposed by the rapid evolution of Command, Control, Communication, Computer and Information (C4I) systems and their related technologies. The aim of the study is to make recommendations concerning the knowledge to be acquired by the military officers concerning future C4I systems and technologies. This is achieved by presenting the evolution of C4I systems, by considering future C4I systems, and by introducing novel approaches for the execution of military tasks.

RÉSUMÉ

Ce document du CRDV répond à la demande du conseiller spécial du chef du personnel de la défense en vue d'évaluer l'état éventuel de la technologie de l'information en 2020. Les résultats de ce travail seront utilisés pour l'analyse des besoins en formation des officiers militaires canadiens pour qu'ils puissent faire face aux défis et demandes imposés par l'évolution rapide des systèmes de commandement, contrôle, communication, ordinateur et information (C3OI) et des technologies connexes. Le but de l'étude est de produire une liste de recommandations visant les connaissances à être acquises par les officiers militaires concernant les systèmes et les technologies C3OI du futur. Ce but est atteint en présentant l'évolution des systèmes C3OI, en considérant les futurs systèmes C3OI, et en introduisant des approches nouvelles pour l'exécution des tâches militaires.

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EXECUTIVE SUMMARY

The Defence Research Establishment Valcartier (DREV) was tasked by LGen Roméo Dallaire, Special Advisor to the Chief of the Defence Staff, to assess the state of Information Technology (IT) in the year 2020. This assessment is necessary within the scope of the Statement of Operational Requirement on the Canadian Officership in the 21st Century to support an analysis of the formation requirements of Canadian Military Officers to meet the challenges and demands imposed by the rapid evolution of Command, Control, Communication, Computer and Information (C4I) systems and their related technologies.

This document presents the evolution of C4I systems from their existing, largely compartimentalized, rigid and hierarchical structures to a foreseen fully integrated and versatile structures. The future C4I systems are described as offering both (a) a completely automated approach for routine operations now requiring either human rote intervention, extensive calculation effort, or complex algorithms, and (b) a closely integrated human-computer interaction approach for operations assisting military officers in better exploring, analysing and understanding the available tactical picture and the possible Courses of Action (CoA). Furthermore, 2020 C4I systems are presented as capabilities allowing users to apply their owns skills and, at the same time, as tools providing appropriate assistance to compensate for their limitations.

The document includes a series of recommendations showing how users could fully benefit from new C4I systems and stressing the importance of appropriate education and training, particularly to make the best use of modern interfaces. Finally, from the IT scientists, the knowledge to be shared among the military officership community is presented under four specific topics.

LIST OF ACRONYMS

CFC	: Canadian Forces College
CFRETS	: Canadian Forces Recruiting, Education and Training System
CoA	: Course of Action
CRDV	: Centre de Recherches pour la Défense Valcartier
C3OI	: Commandement, Contrôle, Communication, Ordinateur, et Information
C4I	: Command, Control, Communication, Computer and Information
DREV	: Defence Research Establisment Valcatier
IT	: Information Technology
OODA	: Observe, Orient, Decide and Act
RMC	: Royal Military College
R&D	: Research and Development
SME	: Subject-Matter Expert

1.0 INTRODUCTION

This study was undertaken within the scope of the Statement of Operational Requirement entitled "Canadian Officership in the 21st Century". LGen Roméo Dallaire, Special Advisor to the Chief of the Defence Staff, tasked DREV to assess the state of Information Technology (IT) in year 2020 to support an analysis of the formation requirements of Canadian Military Officers to meet the challenges and demands imposed by the rapid evolution of Command, Control, Communication, Computer and Information (C4I) systems and their related technologies. The study covers the evolution of C4I systems, those that will definitely be available in 2020, and novel approaches to executing military tasks. It concludes with a series of recommendations concerning the knowledge related to future C4I systems and technologies to be acquired by military officers.

2.0 THE EVOLUTION OF C4I SYSTEMS

Military Forces worldwide recognize that a tremendous quantity of diversified activities occur during modern warfare. Commanders are soon overwhelmed by torrents of data – much of it of no immediate interest – while information needed to make responsible and effective decisions may not be available, or may be badly out of date or of poor quality. Military organizations are, therefore, turning more and more to sophisticated computerized systems to come to grips with the problems of decision support and management of battlefield information.

C4I systems of the future will be the centerpiece in the fight for information dominance over the adversary and vital elements in the effective conduct of missions imposed anywhere within the full spectrum of conflict. Looking towards the year 2020 and beyond, one can foresee evolution in C4I systems from existing, largely compartimentalized, rigid and hierarchical structures to fully integrated and versatile structures. In such C4I systems: (a) the information boundaries between the various levels of command, and between the commander and his specialized support functions will be largely eliminated; (b) the information infrastructure will be totally flexible, as dictated by operational needs, allowing for rapid yet secure reconfiguration of the command structure; (c) sensing and intelligence systems will provide detailed, consistent and up-to-date information in every aspect of the battlespace, including details of friendly and enemy resources; (d) the waging of information warfare, which implies planned attack on enemy's information systems, will be as crucial as the waging of physical warfare; and (e) with the availability of such systems, each decision-maker in the chain of command will be assisted by very powerful decision support tools.

3.0 ANTICIPATED 2020 C4I SYSTEMS

Future C4I systems will offer both (a) a completely automated approach for routine operations now requiring either human rote intervention, extensive calculation effort, or complex algorithms, and (b) a closely integrated human-computer interaction approach for operations that assists military officers in better exploring, analysing and understanding the available tactical picture and possible Courses of Action (CoA). These

approaches will distribute tasks to interoperable functionalities provided by different systems in a totally transparent manner to the end-user. 2020 C4I systems will be based on human-task oriented approaches that may be represented by a model such as the Observe, Orient, Decide and Act (OODA) loop (Fig. 1) for creative activities, decision-making and task execution. These novel systems will be capable of adapting themselves to specific end-user needs and preferences at tactical, operational and strategic levels.

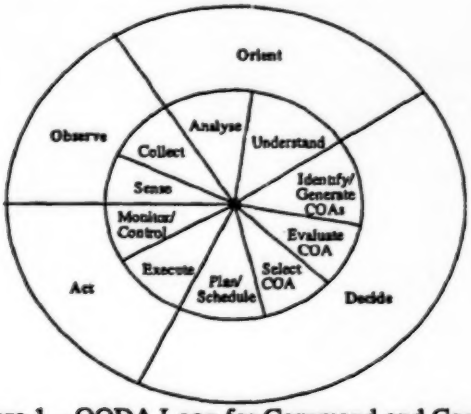

Figure 1 – OODA Loop for Command and Control

C4I systems will be integrated in each phase of the OODA loop to provide the end-user with state-of-the-art working capabilities. They will include capabilities to collate information from different sources and agencies, and provide military officers with specialized tools to very rapidly assess this information. For example, these systems will provide simulation, analysis, comparison, and what-if tools to facilitate understanding of a situation and selection of the appropriate operational CoA. C4I tools will provide assistance during creative efforts such as generation of exercise scenarios, generation of CoA, planning of missions, and so on. These tools will provide valuable help by proposing previously applied solutions and new alternatives. Highly adaptive scheduling and monitoring tools will propose modifications of a set of plans according to environment changes and specified preferences from the organization and end-users. Post-execution analysis tools will help in the compilation and analysis of a military operation in its whole, compare it with previous exercises and operations, and suggest improvements to be considered. These lessons learned will become part of the organization's knowledge. Interactive coaching functionalities will also provide warnings to make sure that military officers follow their doctrine while not neglecting strategic, political, economic and administrative considerations. All the above listed tools will offer facilities to explain why they came to such end results via explanation mechanisms.

Because of the Combined and Joint nature of the work during future operations, collaborative tools will become essential. These capabilities will be used to facilitate progress at meetings, teamwork approaches, and group decision-making processes, including brainstorming and consensus building within a group of people. These tools will also facilitate any type of operation carried out with allied nations and partners.

The whole range of C4I systems will be implemented upon a robust software infrastructure composed of multidimensional datawarehouses. These datawarehouses will be physically distributed among all C4I components and will allow data, information and knowledge sharing-capacities that were previously only accessible to stand-alone applications and their (non-shared) storage information systems such as database, information and knowledge-base management systems. Stored information and knowledge will be rapidly accessible by any C4I system component through advanced visualisation mechanisms. These visualisation mechanisms, which are part of the interface, will ensure a high quality interaction between the end-user and the C4I system.

The perception and understanding of any information and knowledge are highly influenced by the way the information or knowledge is transmitted from the computer to the user. The major part of information acquired by the human during daily activities is through visual and auditory capacities. Thus, it is not surprising that most of the information transmitted by a computer-based system is via these means. One may claim that these media will be favoured by the designers of future systems and that major improvements in visualisation will be related to the richness of the picture and the accuracy of the information. Presently, R&D activities are carried out to improve the robustness of screens, to decrease their weight and increase their size. Some other possibilities of input devices are being developed such as speech recognition, touch screens, data gloves and handwriting recognition. All these devices are designed to dissociate the input transmission activity from skills-like typing or computer-language knowledge. Currently, speech recognition is limited to the use of single isolated words and is speaker-dependent. Again, R&D work is being pursued to extend the use of speech recognition to continuous speech and to be speaker-independent. High-precision touch screens will allow actions like line drawing, dragging, sliding, typing, and direction and velocity sensing. Also, improvements are expected in 3D technologies and in multi-media interface design. Three-dimensional animation is likely to become an important part of any general-purpose interface.

4.0 NOVEL WORKING APPROACHES

An effective C4I system should allow users to apply their skills and, at the same time, provide support to users' limitations. Thus, both system designers and human factor specialists must be involved in the design process of any C4I system as Subject-Matter Experts (SMEs) of the task for which the system is designed. SMEs provide a description of task constraints. Human factor specialists identify human skills and limitations related to the execution of the task and the implication of specific C4I systems. System designers identify and develop technological solutions according to the task constraints, and human skills and limitations. As shown in Fig. 2 by the unidirectional arrows linking the *task* and the two others elements (*system* and *human*), the *task* influences the way C4I *systems* are designed, the training of *human* to perform the *task* with the assistance of these *systems* and the way the *task* must be supported or automated.

By allowing a bi-directional influence between the *task*, the *human* and the *system* elements showned by the curved arrows in Fig. 2, the technological evolution could

propose new ways to execute the *task* that are better adjusted to the environment. The change in performing the *task*, would in turn produce a change in skills and resources required by the *human* to perform the *task*. However, the change of *human* skills and resources introduced by a new *system* would be supported by a deep understanding on how the *human* perceives the *task* (link between *human* and *task*). The new way to perform the *task* could be a better fit with the *human* perception of the *task* adjusted to his/her skills and resources. Within the new *system*, the combination of *system* resources and *human* skills would then be optimal. The development of new *human* skills could also influence an improved version of the *system*. This cycle would ensure an evolution of the military industry to cope with the technological evolution and *human* needs.

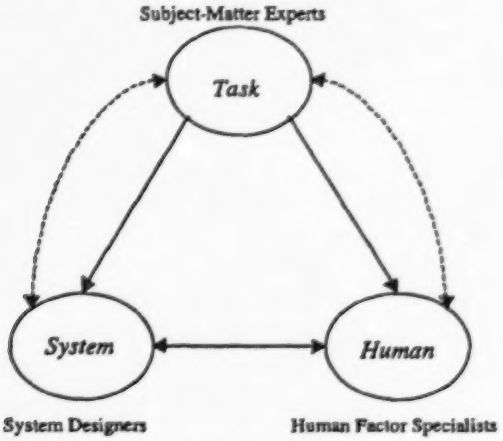

Figure 2 - Triad of elements

5.0 RECOMMENDATIONS

To fully benefit from new C4I systems, military officers will need to have a good level of trust in these systems and feel comfortable with the offered computer-based interface. The way such systems are introduced to users will determine the degree of acceptance and utility in their day to day work. Training and simulation play a major role in the introduction phase of any new system. However, some specific conditions related to a real situation, may not be reproduced. It is then important to understand the effect of the absence of such conditions in a simulated situation. Studies will be needed to evaluate the degree of fidelity and realism required by training and simulation resources.

Even though robustness of C4I systems, as well as training and simulation exercises, will play a major role in the acceptance process, it will nevertheless be possible to speed up this process, and at the same time, increase the trust level. To do so, it is important to make the high-tech world of information technology more accessible to everyone in the military organization. First, everyone in the Canadian Forces should acquire a good knowledge of the different concepts and terminology related to information technology, and a good understanding of their use. Moreover, the knowledge of the real benefits and limits of information technology will demystify the information tools and make them

more attractive to users. Furthermore, military people will need the appropriate education and training to regularly acquire the knowledge of new/adapted C4I systems and their functionalities. This basic knowledge of information technology shared among the Canadian Forces staff would create a synergetic effect so that existing functionalities would be used more effectively. It will also be important that all those in strategic decisional positions be aware of upcoming technologies and systems. A knowledge of the R&D activities will allow military officers to better understand and integrate future systems in their day to day operations. Finally, fully knowledgeable military officers will be in a position to influence the R&D program to produce better systems for the accomplishment of their difficult tasks.

The use of C4I systems will necessitate specialized training to acquire specific skills that are highly related to the way the information is transmitted between the user and the computer. 2020 C4I systems will make use of novel interfaces that will be better adjusted to human information processing. These interfaces will force the development of new user skills, including management of information produced by the ever increasing number of information sources. The interaction between the user and the system will not be restricted to a keyboard or a mouse. For instance, speech recognition will allow the user to work with his hands free for other activities that will be performed concurrently. Studies will be necessary to identify which tasks could be performed concurrently without interference and those that would not be compatible.

6.0 CONCLUSION

Up to now, the transfer from the use of paper and pencils to the use of C4I systems where the human and machine are fully integrated was slower than expected. Even if certain environments have done better than others, significant progress is still needed to deploy and make use of efficient C4I systems. Success in integrating C4I systems in military operations will require an important change in the philosophy of systems development and in the knowledge to be acquired by all those involved (from the R&D community all the way to end-users). The delivery of trustworthy systems, the insertion of new technologies in operational decision-aid capabilities, a good knowledge of military needs by the R&D scientists and engineers from industry, as well as better communication between the various stakeholders will accelerate the system integration process within the Canadian Forces.

In summary, from the point of view of IT scientists, the knowledge to be shared among the military officership community should cover the four following topics:

- Concepts and Terminology
- Understanding and Use of Technologies
- Existing C4I Systems and their Functionalities
- Upcoming Technologies and Systems

The Officer Professional Development program should include these four knowledge topics in order to cover current and upcoming information management technologies, and

state-of-the-art C4I systems that will be available in 2020. The involvement of the R&D community in such a program definition would certainly be desirable.

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